THE USE OF RADIOACTIVE MATERIAL AS A MILITARY WEAPON

Report of Subcommittee of the S-1 Committee on the use of radioactive material as a military weapon.

A. Availability of Material

1. There can be no question but that it is now possible to prepare large quantities of radioactive material in connection with the operation of what is known as either the graphite or the heavy water pile. As the plans now stand in the United States, it should be possible when the full units are in operation along these lines to produce approximately the equivalent in radioactive effect of one ton of radium every four days. Since the material produced is approximately 100,000 times more active than radium itself, the actual quantity of material produced will be very much less than a ton, indeed will only be approximately 20 grams in the pure state and not more than 100 lbs. in the impure form in which it might readily be obtained as a by-product of the pile.

There is no way of estimating accurately what the Germans may be able to do, but it is entirely possible that they may soon be in a position to produce similar material, though probably not at the rate indicated. There can be no question but that it would be much easier to produce this radioactive material than to isolate and purify the final product from one of these piles in order to make a high explosive bomb. Therefore, if the tactical and strategic advantages of using radioactive material appeared to be very great, one might expect the Germans to use their knowledge of applied nuclear physics to this end even if they had not yet been able to accomplish the production of a usable atomic explosive.

B. Contamination of Large Areas of Enemy Territory

2. On the basis of the present available information, it has been estimated by those who are most familiar with biological effects of radioactivity that if the equivalent of a ton of radium (which in scientific terms is called 10^6 curies) were uniformly distributed over an area of approximately two square miles of open

fields,* the area so contaminated could not be occupied by human beings with safety except for short periods of time. Based on calculations and on some preliminary experiments carried out on a small scale by Dr. Stafford Warren, it would seem that the radiations over such territory would correspond to approximately 50 to 100 roentgen units per day at the height of one meter above the ground.

In an area so contaminated, exposure for a few hours would probably produce little or no effect, but exposure for one day would give temporary incapacitation for a large fraction of those so exposed; exposure for two or three days would give prolonged incapacitation and in some cases death would ensue. The area would be lethal for those who occupied it for more than a week. Hence, evacuation would be necessary. Since the effects of such exposure are delayed by days and sometimes weeks, the weapon would be of little value as a means of quickly putting out of immediate action those who were exposed. On the other hand, extraordinarily high concentrations might cause symptoms to appear in a few hour For example, concentrations five to ten times the amount considered in the preceding paragraph (i.e. 500 to 1000 roentgens per day) would be lethal in a day and would seriously incapacitate after a few hours' exposure. These concentrations could be obtained by distributing 10^6 curies over 0.2 to a half of a square mile. The availability of material, however, would limit such heavy dosage to something like two such applications per week or the equivalent.

Areas contaminated by radioactive materials would continue to be dangerous until the natural decay of the radioactivity had lowered the radiation to a safe point. With the materials in view, this would require many weeks if not months.

*Uniform distribution is assumed for purposes of calculation. Probably two or three times the area would be effectively contaminated if the distribution were spotty, but the highly active spots were not too far apart and the intermediary zones had some activity. On the other hand, if the lack of uniformity corresponded to highly active areas, a few yards square every half mile the area would hardly be effectively contaminated.

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This persistence of contamination in spite of all efforts to decontaminate constitutes the chief tactical advantage of this weapon as compared to contamination with mustard gas or lewisite. If the surface were hard, some decontamination might be accomplished by washing with large volumes of water, but in general it may be stated that no general method of decontamination appears possible. A secondary but perhaps almost equally important advantage of radioactive material lies in the fact that it would be impossible to develop protective clothing which could be worn by those who were to occupy or traverse the area so contaminated. Here again the difference between radioactive material and such poison gases as mustard gas and lewisite is evident.

C. Radioactive Gas Warfare

3. In the preceding two paragraphs, we have considered only the use of radioactive material from the point of view of contamination of an area. The effectiveness of such contamination arises from the fact that the radioactive substances give off penetrating gamma radiations more or less equivalent in their biological effects to x-rays. A somewhat different use of the radioactive material would depend on the fact that extremely small quantities of certain of the radioactive elements appear to be absorbed in the lungs of animals and produce fatal effects after a period of some weeks. The amounts necessary to produce eventual death under such conditions are extraordinarily small. As little as a total accumulation in the lungs of radioactive material of only 10^{-6} grams would be fatal. This means that if such materials could be kept in the air in the form of a fine dust or smoke in concentrations as low as two thousandths of a microgram per liter, inhalation of such atmosphere for one hour would be sufficient to establish a lethal concentration; the material would accumulate in the lungs and the individual would eventually die of the radioactive poison. There is no known way in

which such a contaminated individual could be successfully treated once he had thus been exposed. These results in regard to the effect of inhalation of radio-active dust are based on preliminary measures and cannot be considered as final. Nevertheless, they are so striking as to deserve careful consideration.

The particular elements which appear to accumulate in the lungs constitute a major portion of the radioactive by-product of the piles. While a gas mask with a good filter (the standard combat mask today) would eliminate almost all the radioactive dust from the atmosphere and thus provide protection, two alarming facts must be borne in mind. First, the concentrations we are considering are too low to be seen and the material is odorless and without taste, so it would be difficult to know when to "mask up"; second, even the best masks will allow the penetration of a 0.1 percent of dust if the particle size is about 0.2 microns. Therefore, with concentrations of one microgram per liter (still invisible), an hour's exposure (1000 liters inhalation) might be fatal even with the best mask. On the other hand, there is fortunately one offsetting factor; a dust as fine as 0.2 microns per liter and a concentration of the order of 1-10 micro-grams per liter would behave essentially like a gas. The material would not settle but would disperse with winds and temperature differential just as does phosgene. Therefore, all the difficulties of "keeping up concentrations" for more than a few minutes familiar to those concerned with gas warfare would be at hand. It is the long delay in the effect of the material, however, which would be the chief factor in militating against its use as a poison gas.

D. Offensive Uses by the Enemy

4. From the above very brief summary of the essential elements in regard to the use of radioactive material in warfare, the following points seem clear in regard to the possible offensive use of such a weapon:

(a) The use of the material to produce the maximum eventual fatalities would consist in developing ways and means of keeping in suspension in the air in the form of very fine dust or smoke certain of the radioactive materials. But it is not an easy problem to devise munitions capable of setting up such clouds of dust or smoke and difficult to keep such clouds from dissipating. Furthermore, the fatalities from radioactive gas warfare would not develop for some weeks, and therefore while the eventual effect on the enemy might be catastrophic, immediate effect on fighting troops would be small.

(b) The use of radioactive material to cause the maximum immediate military effect would appear to lie in the possibility of the contamination of open ground to give sufficiently high radiation over an area to render the area uninhabitable. The chief problem lies in devising suitable munitions which would give a fairly uniform distribution of the radioactive material over the ground chosen for contamination.

It is clear that if the contamination is to be effected from high altitudes by bombs dropped by planes, a difficult problem is at hand. In the first place, each bomb must be heavily shielded with lead in order to protect the crew of the plane and those handling the bomb on the field when the plane is loaded. It has been estimated that 310 lbs. of lead would be needed for each bomb carrying 10,000 curies. (The contents of such a bomb if uniformly distributed could contaminate approximately 250,000 square feet so that the radiation was the order of 100 roentgens per day and the area uninhabitable except for a few hours.) It is evident that in order to have such a bomb distribute its contents in the form of a dust over an area would require (1) carefully regulated methods

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of ejecting the contents a certain distance above the ground, and (2) the control of particle size so that the dust would settle rapidly before dissipation by air currents. The radioactive material would be mixed with, say, 50 kilos of inactive solid material for each bomb of 10^4 curies and the particle size regulated by grinding to 5-10 microns. The bomb should be arranged to burst in the air a thousand feet above the ground with as low a wind velocity at the time of attack as possible. It has been estimated that under those conditions with zero wind velocity the area covered would be of the order of magnitude required,- namely, 250,000 square feet. On the other hand, with a wind velocity of 5 to 10 miles per hour dissipation would result in the dust settling over 50 to 100 times as large an area with the resulting 50 to 100 times lower concentration. This wide area would be so lightly contaminated as to be habitable for many days or perhaps weeks without serious damage to personnel.

It is clear that if one proposed to contaminate an area as large as two square miles or so by the use of such bombs, some 80 to 90 bombs would have to be dropped at nicely spaced intervals so that there was neither an overlap nor great areas in between each bomb pattern, and the meteorological conditions would have to be accurately estimated in advance. The tactical problems involved in accomplishing any such bombardment from the air at high altitudes are obviously very great.

The above statement of the problem represents the simplest case where contamination of open fields or areas is under consideration. For built up sections where a considerable amount of concrete or brick or tile is used, a much less favorable situation exists from the point of view of

one desiring to use this weapon. Dr. Stafford Warren estimates from his experiments that something approaching 100 times greater concentrations would have to be set up in such built up areas in order to be as effective as in open fields. If one goes to such concentrations, it seems clear that the capacity for producing the radioactive poison might be the limiting consideration, though one must also consider that the number of bombs and planes would also go up by a factor of 100.

The use of much larger bombs than those carrying 10^4 curies would be difficult because of the necessity of cooling down large amounts of the radioactive material which tend to heat up because of the energy involved in the disintegration which is proceeding all the time.

(c) From considerations of (a) and (b) above, it is evident that considerable experimentation with actual field trials would be necessary to determine the optimum conditions under which radioactive dusts could be disseminated either for lung contamination or ground contamination. Such tests could be very readily carried out by using very small amounts of radioactive material (tracer amounts) and studying the concentrations in the air or on the ground by means of sensitive physical instruments which are now readily available. It is the recommendation of this Committee that <u>if</u> military authorities feel that the United States should be ready to use such weapons in case the enemy started to use it first, such studies should be initiated immediately. These studies could be carried out best by a group containing some men who are familiar with the particular project which is planning to produce this radioactive material and others drawn from NLRC who are working on the development of munitions for dissemination of dust and liquids and still others drawn from NLRC who are familiar with the field testing of chemical warfare agents.

(d) To the writers of the report, it appears that the difficulties of devising munitions to produce satisfactory concentrations of radioactive material over enemy territory from planes are very great, so great in fact that it makes the use of this weapon in this form by the enemy with significant military effectiveness a rather remote possibility. In the hope, however, of a great psychological effect, such use by the enemy might well be undertaken.

A much easier way of employing the same basic principle would be to use radioactive material to render unsafe territory evacuated in the face of the approaching enemy. In this case, the dust could be uniformly distributed over the ground either by (1) low flying planes, (2) actual spraying of buildings, streets, air fields and railroad yards from automobiles carrying lead coated tanks of a solution of the material, or (3) by land mines (lead coated) which could be properly spaced and set off at a distance. The chances of the Germans using some such method of radioactive warfare seem to the writers of this report much greater than the other possibilities and, indeed, sufficient to warrant defensive procedures being instituted at once in armies planning to pass over territory evacuated by German troops.

E. Defensive Measures

5. The writers of this report feel that from a defensive point of view, one can consider it unlikely * that a radioactive weapon will be used against the continental United States. They further believe that if such a weapon were used against a populated industrial city such as London, an automatic alarm would be provided by virtue of the fact that a concentration of material sufficient to

*The Chairman of the Subcommittee, James B. Conant, feels that it is extremely unlikely that a radioactive weapon will be used against the U. S. and unlikely that the weapon will be used at all.

cause serious damage to any portion of the population in a few hours would also fog all photographic films and give strange effects in various pieces of physical equipment in the scientific establishments of the city. If the material came down from the air as a cloud of dust, it would also probably produce strange effects in the radar equipment. Therefore, special precautions for alerting a city such as London would not seem very difficult to arrange. It is clear that if radioactive material is found after a bombing raid prompt evacuation, together with the issuance of gas masks with suitable filters (the regular Army mask not the civilian mask) would be in order.

The eventuality outlined above in 4(d),- namely, use by the enemy of such material to render evacuated areas uninhabitable,- seems to us sufficiently great to warrant the issuance of special instructions to at least one officer in each division of any Army which might be faced with such an eventuality. Such an officer should be familiar with the ways of detection and understand the reading of certain instruments which would give the effective radiation and be prepared to advise on the movements of troops in such a way as to avoid more than a passing exposure to high radiation. It would also be of great importance to see that the troops were equipped with the proper type of gas mask and that these masks were put on immediately so that dust could be kept out of the lungs.

Methods of detection based on physical instruments are open to certain objections, since all such instruments are somewhat fragile, and may go wrong in the field through the breaking of tubes, running out of dry batteries, etc. Nevertheless, such instruments would be the only way of controlling evacuation of areas intelligently. They alone could give accurate readings on which judgment must be based. The use of photographic detectors are much simpler and for the purposes of qualitative detection leading to an alarm would be very effective.

It is our recommendation that a special committee composed of Dr. Stafford Warren and Dr. R. S. Stone be asked to prepare a report on both the use of detec in the field and instructions which might be issued to a divisional officer explaining under what conditions troops might be moved through various areas and what methods of decontamination could be tried under certain special circumstances. In short, this committee should prepare a manual outlining adoctrine somewhat similar to that which already exists for the use of gas officers. It is our suggestion that either a divisional gas officer or some special officer attached to the corps or Army headquarters be charged with the responsibility for these defensive measures. Such officer or officers would need to have instruments available and be given authority to trayerse all areas which previously had been occupied by the enemy to test possible radioactivity while such areas were being occupied by our own troops.*

F. Probability of Use by Germans

6. Finally, we may venture a few remarks on the probabilities of use of radioactive warfare by the Germans. On the factors which make such an eventuality probable, one must say that as a method for rendering evacuated areas uninhabitable the weapon seems to have considerable potential possibilities, provided sufficient quantities can be produced. If the Germans could produce at the rate estimated for the United States, it would be possible for them to contaminate effectively approximately four square miles per week. While this is not a very large amount of ground, the contamination of small critical areas such as airports and railroad yards might be of determining significance. If the enemy were successful in devisir

*Two of the signers of this report, A. H. Compton and H. C. Urey, feel that the immediacy of the danger is sufficient to warrant a recommendation that in addition to providing divisional officers properly equipped and instructed, detecting devices shall be placed with each unit of one hundred men.

methods of keeping the radioactive material in the form of fine dust over a long period of time and therefore use method 4(a), then the weapon becomes a form of poison gas warfare and might be many more times as effective. Unless our troops were promptly "masked up," the eventual fatalities might be very serious. On the other hand, the delayed effect seems to mitigate against the use of this particular weapon.

The direct use of it as a destructive weapon against such a city as London seems to us extremely remote because of the large quantities of material which would be required for any effective concentration. Because of the shielding effect of buildings, concentrations in built up areas would have to be probably 100 times greater than those in open fields on which we based the statements made in the first part of this report. On the other hand, the effect on the morale of the population might be considerable and the possibility of creating panic would always be in the minds of the enemy.*

*Two of the signers of this report, A. H. Compton and H. C. Urey, desire to strengthe the recommendations of this report and emphasize their feeling of urgency by inserting the following to which the Chairman of the Committee cannot agree:

"For its psychological effect, use of radioactive poisons by the enemy before they expect us to be ready would presumably be the preferred strategy. An estimate of the best time schedule possible for the Germans indicates that they might possibly be ready to use radioactive materials in quantity by the autumn of 1943. Thus an attack within the next few months may be expected if it is to be made at all. Immediate preparations for reply accordingly become important unless there are reasons, unknown to us, for discounting the probability of use of radioactive warfare by the enemy.

"Perhaps the most effective reply would be to answer immediately in kind. This would warn the Germans that we are prepared for their "surprise" with the implication that we will follow through as far as is necessary for victory. If theirs is a hope borne of desperation, such a reply might lead to early surrender. An effecti reply which could be ready by December, 1943 would be several bombs of 10,000 curies each prepared at the Clinton plant. The preparation of such bombs would retard perhaps by a few days the development program for 49 production. This procedur would require consultation with an expert on aerial bombs, and preparation to extract and deliver the radioactive material in the needed form. Immediate action is necessary if such devices are to be available before the end of 1943."

If the Germans were to use this form of warfare, it would be self-evident that ordinary gas warfare would be used in retaliation, and with the control of the air in our hands, it would seem rather a last resort for the Germans to undertake such a venture. Of course, the controlling factor, which none of us can tell, is where the Germans stand on the manufacturing aspects of this problem. We can only state with definiteness that there is a possibility if not a probability that they are now fairly well along on such a procedure. Weighing all the pros and cons, it is the view of the writers of this report that on balance it would be unwise not to have some precautions taken by invading armies even if the possibility of radioactive warfare being used against them is exceedingly remote.

James B. Conant, Chairman

A. H. Compton

H. C. Urey

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No information has been uncovered which would indicate that the Germans could not produce radioactive materials in sufficient quantity by December 1943 to use them as a military weapon. If they did so, they could force evacuation for a period of at least a week of areas of approximately two (2) square miles every four days. The areas could be an occupied city such as London or an important military point such as a railroad junction. It would not be practicable to decontaminate these areas. Only time could decontaminate the area.

While it is extremely unlikely that a radioactive weapon will be used against the United States territory and unlikely that the weapon will be used at all, still preparations must not be neglected against such a possibility.

RECOMMENDATIONS:

1. That a small group of officers be trained on the technical aspects of this phase of warfare and then attached to American Headquarters in London in order that they can give prompt information in the event of any real or suspected use of this material by the enemy. These officers should do this as an additional rather than a primary duty.

2. That we continue to improve methods of detection and protection The first of these recommendations would require the approval of the Chief of Staff. The second is now being carried on under my direction and will continue to be carried on unless instructions are received to the contrary.

3. That we procure and maintain a small number of portable detection equipments

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